INTRODUCTION

The proliferation of wetland enhancement and creation projects during recent decades has led to some unusual solutions for creating wetland hydrology, particularly in regions where water is scarce or regulatory constraints prohibit tapping into ready sources of water such as rivers or adjacent bays and estuaries. One of these solutions involves using treated or "reclaimed" wastewater to create or enhance wetland systems. Typically, these projects involve flooding wetland areas either perennially or seasonally with reclaimed water to create specific types of wildlife habitat, including foraging areas for overwintering or migrating waterbirds.

However, use of reclaimed water for wetland enhancement or restoration has raised concerns over the potential impact of reclaimed water on existing biota. While the use of constructed wetlands for treating wastewater is widely accepted, the potential for using reclaimed wastewater to create or enhance wetlands is still greeted with skepticism from many regulators and biologists. In 1991, a San Francisco Estuary Project report (ABAG et al. 1991) stated that "a coordinated monitoring effort needs to be conducted by the EPA (Environmental Protection Agency), Regional Water Quality Control Board (RWQCB) or similar entity to determine level of effects, if any, and provide guidance or cautions for future applications" of using wetlands for storing or treating wastewater or using wastewater for wildlife enhancement. Some concerns focus on discharges of low salinity water into areas or during seasons where high salinities are typically present, but for most the crux is the potential for anthropogenic eutrophication and the ecological fate of contaminants such as metals, pesticides, and polychlorinated biphenyls (PCBs), particularly in estuaries.

While pollutants enter estuarine waters through discharge of effluent or other sources such as riverine flow or sediment resuspension, most are ultimately deposited within sediments, where concentrations can exceed that of the water column by an order of magnitude. Once deposited in sediments, pollutants can become available for uptake into the biotic "food web" and, in some cases, certain pollutants bioaccumulate in higher order trophic levels (e.g., birds, fish, and aquatic mammals). Benthic filter feeders such as oysters, clams, and various crustaceans absorb dissolved pollutants as water circulates over their gills, and snails and polychaete worms ingest pollutants from sediment particles as they graze on organic matter in the sediment (SFEP 1992). Invertebrates such as these represent the main dietary staple of many estuarine organisms, including birds, fish, and aquatic mammals.

Few reclaimed water wetland creation or enhancement projects exist, therefore, data on the effects and the efficacy of this type of restoration approach is minimal. In the San Francisco Bay area, there are at least three projects that use reclaimed water exclusively for enhancement, including the Hayward Shoreline Reclaimed Water Marsh and the Mountain View Sanitary District Wetlands (Moorhen and McNabney Marshes). These projects have been operational for 10 to 25 years and are reportedly used by thousands of birds annually. During the peak of the Pacific flyway migration, the Hayward Shoreline Marsh attracts close to 20,000 waterfowl and shorebirds (East Bay Regional Parks District (EBRPD) 1996). However, use of reclaimed water for wetland enhancement and creation remains an evolving science. Managers of these areas have grappled with such problematic issues as high concentrations of unionized ammonia,

chlorine-related toxicity, low dissolved oxygen (D.O.), avian cholera outbreaks, and conversion of brackish marsh to freshwater marsh habitat (EBRPD 1996; Kenneth Burger, stewardship manager, EPRPD, *pers. comm*.; Richard Bogaert, biologist, Mountain View Sanitary District, *pers. comm*.). Many of these issues have been subsequently resolved by treatment process changes (e.g., increased removal of ammonia or fine-tuning of the dechlorination process) or water management (K. Burger, *pers. comm*.; R. Bogaert, *pers. comm*.). However, some problems may not be so easily resolved. During a mercury bioaccumulation study conducted at Hayward Shoreline Marsh in 1995, some black-necked stilt (*Himantopus mexicanus*) eggs were found to have somewhat elevated concentrations of mercury, although the source of this mercury was unclear (EPRPD 1996).

During the 1990s, the California Department of Fish and Game (CDFG) began to evaluate using reclaimed water for one of the largest wetland restoration projects in the history of San Francisco Bay: the 10,000-acre former Leslie-Cargill salt pond complex in San Pablo Bay (Napa-Sonoma Marsh Project). Preliminary analyses indicated that some of the more saline ponds would require large volumes of freshwater to reduce salinity to acceptable levels for either discharge to San Pablo Bay or habitat enhancement. Use of river water for dilution appears to be constrained by the need for fine-meshed fish screens to ensure that the project did not entrain threatened or endangered fish species, such as the Delta smelt (*Hypomesus transpacificus*), and other sources of water were cost-prohibitive. At the time, CDFG was already working with the Sonoma Valley County Sanitation District (SVCSD) in managing use of reclaimed water for not only its own Ringstrom Bay unit, but for SVCSD's Hudeman Slough Mitigation and Enhancement Wetlands (Hudeman Slough Enhancement Wetlands) Project. In 1990, SVCSD was required to mitigate for construction of reclaimed water storage ponds by both enhancing and creating wetlands along the upland ecotone of San Pablo Bay. This involved enhancement of diked subsaline seasonal wetlands, as well as muted tidal marsh, and creation of seasonal wetland and perennial freshwater marsh ponds.

In the more than 10 years since the Hudeman Slough Enhancement Wetlands Project was completed, the Enhancement Wetlands have attracted thousands of overwintering and migrating waterbirds. Despite this success, regulators still have serious concerns, in large part due to the lack of quantitative study on the effects of using reclaimed water for restoration and enhancement. Other than the projects referenced above, little detailed information about these type of projects exist, particularly wetlands projects oriented exclusively at enhancing wildlife habitat rather than treating wastewater. Mitigation monitoring of wildlife and vegetation had been performed after implementation of the Hudeman Slough Enhancement Wetlands Project, but no detailed ecological studies had been conducted. In 1999, SVCSD, through its agent, the Sonoma County Water Agency, launched a two-year study to evaluate the ecological health and status of the project. The study compared water and sediment nutrients, sediment contaminant levels, vegetative communities, benthic invertebrate and zooplankton densities, and avian use between the Hudeman Slough Enhancement Wetlands and nearby hydrologically managed and unmanaged wetlands.

STUDY AREA

Description

The Study Area is located in the northern portion of San Pablo Bay in north San Francisco Bay, California (Figure 1). The areas studied represented historic or current marshlands in San Pablo Bay and ponds in the ecotone between the marshlands and adjacent upland areas. Most of the San Pablo Bay marshlands have been altered through diking and subsequent use for agricultural purposes such as hay farming, grazing, and vineyards. However, some of these former marshlands have reverted back to wetlands either through a lack of levee maintenance or enhancement and restoration programs.

The Hudeman Slough Enhancement Wetlands are located near the town of Schellville in Sonoma County (Figure 1). The project resulted from mitigation for the construction of SVCSD's reclamation storage ponds. Some of the property had already begun to revert to wetlands after hay farming ceased. The mitigation plan called for enhancement of these existing wetlands through hydrologic management with reclaimed water (Management Units 1 and 3) and construction of upland ponds (Upland Ponds 1-10) that would be inundated with reclaimed water either perennially or seasonally (Figure 2). Hydrologic management of these areas is specifically aimed at enhancing habitat for migrating and overwintering waterbirds. In addition, one area (Management Unit 2) was set aside to be passively managed as a pickleweed *(Salicornia virginica*)-dominated salt marsh and potential habitat for the state- and federally-listed endangered salt marsh harvest mouse (*Reithrodontomys raviventris*, Figure 2). All of the Management Units and Upland Ponds are isolated from the adjacent creek and slough by levees (Figure 2), which prevent surface water flow from Hudeman Creek or Hudeman Slough entering into the Enhancement Wetlands. During certain times of the year, water is allowed to discharge from the Enhancement Wetlands into Hudeman Slough. Hudeman Creek is a small perennial creek that drains a largely agricultural watershed, which supports vineyards and dairy and beef cattle operations.

CDFG manages diked marshlands within the Napa-Sonoma Marsh in the northern portion of San Pablo Bay, many of which were once used for hay farming. These units include Ringstrom Bay, which is located adjacent to the Hudeman Slough Enhancement Wetlands; Huichica Creek; and Buchli Station (Figure 2). Most of these units are actively managed for migrating and over-wintering waterbirds by operation of tidegates that allow tidal flooding during the fall and early winter. CDFG also maintains several perennial ponds that are actively managed with pumped groundwater rather than tidal flooding. Adjacent to the managed diked units are areas that CDFG does not actively manage, including undiked and diked marshes, and seasonal ponds that are filled during the winter with precipitation, upland run-off, and, in certain instances, overflow from adjacent creeks. Watersheds for the CDFG units are also dominated by agriculture, primarily vineyards and dairy and beef cattle.

Study Design

The Study Area included the Hudeman Slough Enhancement Wetlands and CDFG's Ringstrom Bay, Huichica Creek, and Buchli Station units. The Study Area was divided into eight (8) monitoring units, comprising both managed and unmanaged hydrological regimes (Figure 2).

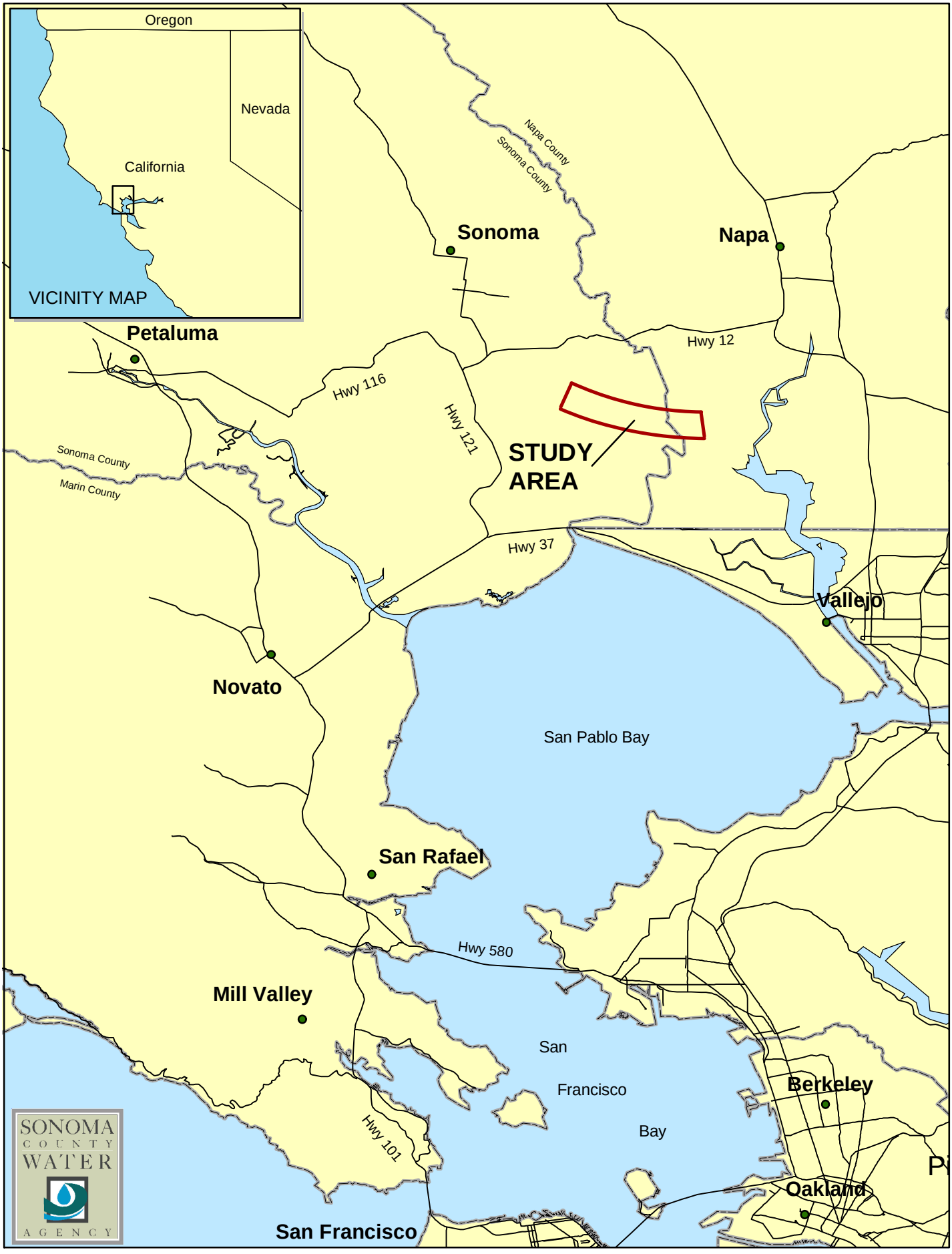

Figure 1. Hudeman Slough Enhancement Wetlands
Case Study Area Location and Vicinity Map

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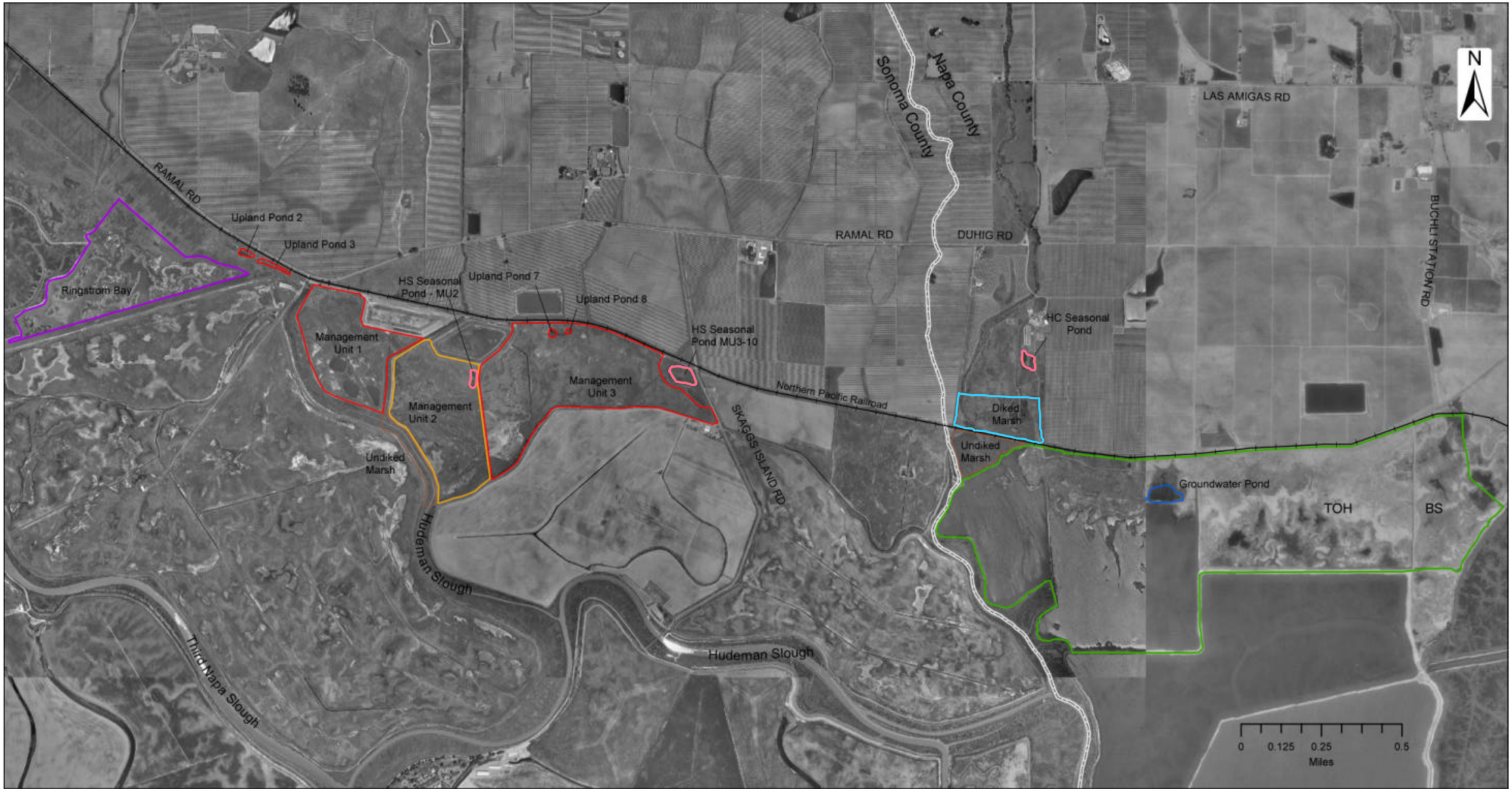

SONOMA COUNTY WATER AGENCY

Dates of Photos:
July 1993 (Napa County)
June 2001 (Sonoma County)

Monitoring Unit Type

Hydrologically Managed
- Reclaimed
- Reclaimed & Muted Tidal
- Muted Tidal
- Passive
- Groundwater

Hydrologically Unmanaged
- Undiked Marsh
- Diked Marsh
- Seasonal Pond

Figure 2.
Location of monitoring units within the Hudeman Slough Enhancement Wetlands Case Study area.

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Hydrologically managed monitoring units included: Reclaimed Water, Reclaimed Water + Muted Tidal, Muted Tidal, Passive Hydrologic Management, and Upland Pond Managed with Groundwater (Groundwater Pond; Table 1). Hydrologically unmanaged monitoring units consisted of Diked Marsh, Seasonal Ponds, and Undiked Marsh (Table 1). To the extent possible, monitoring units were selected with the goal of being as similar as possible in terms of location within the watershed (at the boundary between uplands and San Pablo Bay), former land management (e.g., formerly farmed), types of vegetation communities present (e.g., subsaline seasonal wetland, moist grassland, etc.), and potential for hydrologic input from sources such as run-off from adjacent uplands. The goal was to have the monitoring units differ principally in the source of hydrology (e.g., tidal, freshwater, pumped groundwater, reclaimed water) and the degree of management (e.g., unmanaged, managed, passively managed, etc.). However, the low total number of monitoring units available and the inability to limit differences between units to just hydrologic management method ultimately precluded us from establishing true control or reference sites. Monitoring units represent variations along a hydrologic continuum that ranges from fully tidal unmanaged marshes to non-tidal marshes managed with reclaimed water. A comparison between monitoring units is presented in Table 2. The inability to develop a statistically valid observational study design with an adequate number of replicate monitoring units largely precluded us from conducting formal parametric or non-parametric statistical analyses. For this reason, most of the data was presented simply as means and standard errors or, for exploratory purposes, was analyzed informally using multivariate statistical methods such as ordination (indirect and direct gradient analysis) and cluster analysis.

Hydrologically Managed Monitoring Units

Reclaimed Water. These monitoring units represent areas managed with reclaimed water and consist of six (6) monitoring sub-units in the Hudeman Slough Enhancement Wetlands: Management Unit 1 (MU1), Management Unit 3 (MU3), and Upland Ponds 2, 3, 7, and 8 (Figures 2 and 3). Reclaimed water is used in Management Units 1 and 3 for waterbird habitat enhancement. From May through October (non-discharge season), secondary-level treated wastewater is pumped from the SVCSD treatment plant to the reclamation storage ponds and/or enhancement wetlands and agricultural users. From November through April (discharge season), SVCSD discharges treated wastewater directly to Schell Slough, located northeast of Hudeman Slough, as permitted by the San Francisco Regional Water Quality Control Board (SFRWQCB). Typically, reclaimed water is discharged into Management Units 1 and 3 from September until the beginning of the discharge season in November. In 1999, Management Units were flooded early to allow for emptying and repair of reclamation storage ponds. In November, most of the water within Management Units 1 and 3 are discharged directly to Hudeman Slough to ensure that units do not exceed holding capacity once the rainy season begins. Some reclaimed water is retained in a series of created ponds and drainage channels within these management units. Reclaimed water is also pumped directly into the Upland Ponds from mid-August through April, with two (2) Upland Ponds (including Upland Pond 7 during this study) filled with water perennially. Water levels are maintained within the Upland Ponds and the Management Unit ponds by periodically filling ponds when water levels drop.

Reclaimed Water + Muted Tidal. This monitoring unit, specifically CDFG's Ringstrom Bay Unit, is managed with both reclaimed water and muted tidal flushing through operation of a tide gate. The Ringstrom Bay Unit is located west of MU1 and is separated from the area by a series

Table 1. Hydrologic sources and habitats within the Hudeman Slough Enhancement Wetlands Case Study area.

Sub-Unit	Hydrologic Sources	Habitats[1]
HYDROLOGICALLY MANAGED MONITORING UNITS		
Reclaimed Water Monitoring Unit - Hudeman Slough Enhancement Wetlands		
Management Unit 1 (MU1)	Reclaimed water; moderate upland run-off from vineyards in adjacent uplands; precipitation; possible saline groundwater influence from Hudeman Slough.	Diked saline wetland; non-tidal diked subsaline seasonal wetland; panne; moist grassland.
Management Unit 3 (MU3)	Reclaimed water; substantial run-off from vineyards in adjacent uplands; precipitation; possible saline groundwater influence from Hudeman Slough.	Diked saline seasonal wetland; panne; moist grassland.
Upland Ponds (2, 3, 7 & 8)	Reclaimed water; precipitation; possible groundwater table.	Seasonal marsh; non-tidal diked subsaline seasonal wetland; moist grassland
Reclaimed Water + Muted Tidal Monitoring Unit - CDFG Ringstrom Bay Unit		
Ringstrom Bay	Reclaimed water via T1 intertie; muted tidal flushing during non-discharge season; run-off from adjacent uplands; precipitation; possible saline groundwater table.	Diked saline seasonal wetland; muted tidal diked brackish marsh; moist grassland; seasonal marsh.
Muted Tidal Monitoring Unit - CDFG Buchli Station Unit		
Buchli Station (BS)	Microtidal flushing with flooding/prolonged impoundment during winter for wildlife; run-off from vineyards in adjacent uplands; precipitation; possible saline groundwater table.	Diked saline seasonal wetland; panne; moist grassland.
TOH	Microtidal flushing with flooding and evaporation during winter for wildlife; run-off from vineyards in adjacent uplands; precipitation; possible saline groundwater table.	Panne; moist grassland.
Huichica Creek (HC)	Microtidal flushing with flooding and evaporation during winter for wildlife; run-off from vineyards in adjacent uplands; precipitation; possible saline groundwater table.	Panne; diked saline seasonal wetland; moist grassland.
Passive Hydrologic Management Monitoring Unit - Hudeman Slough Enhancement Wetlands		
Management Unit 2 (MU2)	Flooding from precipitation and run-off from adjacent uplands; drainage through one-way tide gate; precipitation; possible saline groundwater table.	Non-tidal diked brackish marsh; panne; seasonal wetland; moist grassland.
Upland Managed with Groundwater Monitoring Unit - CDFG Huichica Creek Unit		
Groundwater Pond	Active groundwater pumping for wildlife enhancement; precipitation; possible existing groundwater table; upland run-off.	Freshwater marsh.

Table 1 (cont'). Hydrologic sources and habitats within the Hudeman Slough Enhancement Wetlands Case Study area.

Sub-Unit	Hydrologic Sources	Habitats[1]
HYDROLOGICALLY UNMANAGED MONITORING UNITS		
Seasonal Ponds - CDFG Huichica Creek Unit; Hudeman Slough Enhancement Wetlands		
HS Seasonal Pond – MU2 Ref	Precipitation; upland run-off.	Seasonal marsh; moist grassland.
HS Seasonal Pond – MU3 Ref	Precipitation; upland run-off.	Non-tidal diked subsaline seasonal wetland.
HC Seasonal Pond	Tidally influenced freshwater overflow from Huichica Creek; run-off from adjacent uplands; precipitation.	Non-tidal diked subsaline seasonal wetland.
Diked Marsh - CDFG Huichica Creek Unit		
Diked Marsh	Partially diked; high tide and freshwater overflow from Huichica Creek; run-off from vineyards in adjacent uplands; precipitation; possible groundwater influence.	Muted tidal diked brackish marsh.
Undiked Marsh - CDFG Huichica Creek Unit; Hudeman Slough Enhancement Wetlands		
HC Undiked Marsh	Tidal flow from upper arm of Hudeman Slough; freshwater inflow from Huichica Creek; precipitation.	Tidal brackish marsh.
HS Undiked Marsh	Tidal flow from Hudeman Slough; freshwater inflow from Hudeman Creek; precipitation.	Tidal brackish marsh.

[1] Communities adapted from San Francisco Bay Area Wetland Ecosystems Goals Project (1997; unpub. data).

Table 2. Hudeman Slough Enhancement Wetlands Case Study monitoring units.

Water Source[1]	Hydrologically Managed Monitoring Units				Hydrologically Unmanaged Monitoring Units		
	Reclaimed Water	Reclaimed + Muted Tidal	Muted Tidal	Other	Muted Tidal	Full Tidal	Other
Historic or Current Marshlands	Mgt Unit 1, Mgt Unit 3	Ringstrom Bay	BS, TOH, HC		HC Diked Marsh	HC Undiked Marsh; HS Undiked Marsh	
Ponds in Upland Ecotone	Upland Ponds 2, 3, 7 & 8			Groundwater Pond			HS Seasonal Pond MU2 Ref; HS Seasonal Pond MU3 Ref; HC Seasonal Pond

[1] Hudeman Slough Enhancement Wetlands Case Study monitoring units included current and historic marshlands and ponds in the upland ecotone and were selected to represent variations in hydrology that represented a range of treatments from intensely managed to unmanaged areas.

Non-tidal diked subsaline seasonal wetlands with flooded panne areas and permanent ponds receiving reclaimed water at Management Unit 1, Hudeman Slough Mitigation and Enhancement Wetlands.

Non-tidal diked brackish marsh at Management Unit 2, Hudeman Slough Mitigation and Enhancement Wetlands.

Diked saline seasonal wetland, moist grassland, and flooded panne areas at Buchli Station unit, Napa-Sonoma Marshes Wildlife Area.

Open water habitat in seasonal marsh receiving reclaimed water at Upland Pond 7, Hudeman Slough Mitigation and Enhancement Wetlands.

Figure 3. Hudeman Slough Enhancement Wetlands Case Study Monitoring Units.

of dikes (Figure 2). Ringstrom Bay typically receives reclaimed water from September through November 1, but in 1999, the season started in June to allow for emptying and repair of reclamation storage ponds. Ringstrom Bay differs from the Management Units and Upland Ponds in that CDFG allows some muted tidal flushing/inflow of the area from Steamboat Slough in addition to reclaimed water. The slide/flap tide gate system allows tidal water to inflow on 4.5-foot or greater tides and outflow on low tide during periods when reclaimed water is not present (Tom Huffman, Napa-Sonoma Marsh Complex refuge manager, CDFG, *pers comm*.). When receiving reclaimed water, bladders are installed into culverts to prevent leakage of reclaimed water into the adjacent slough and tide gates are closed (T. Huffman, *pers comm*.).

Muted Tidal. This monitoring unit consists of CDFG's Buchli Station Unit (Figures 2 and 3). The two (2) monitoring sub-units, BS and TOH, at the Buchli Station Unit are subsaline seasonal wetlands that receive extremely muted tidal inflow via tide gates located east and west of the sampling areas. Water levels within both sub-units are managed for waterbirds. The Buchli Station Unit is flooded through sheet flow spillover from the borrow ditches channeling tide flow from the tide gates near Fly Bay (T. Huffman, *pers. comm*.). The unit is flooded during the second or third week of August, with water levels maintained artificially until January (T. Huffman, *pers. comm*.). After that, the unit typically floods from precipitation and upland run-off and waters are then allowed to evaporate through spring. The tide gate west of the sampling area, which is the closest to the TOH monitoring sub-unit, was not functioning properly during the study period; so muted tidal flow was coming exclusively from the Fly Bay tide gate.

Passive Management. The Passive Hydrologic Management monitoring unit is Management Unit 2 (MU2) in the Hudeman Slough Enhancement Wetlands (Figures 2 and 3). As noted earlier, MU2 is not actively flooded with reclaimed water and is currently passively managed as pickleweed marsh to maintain potential habitat for the salt marsh harvest mouse. During the winter, particularly in heavy rainfall years, precipitation and run-off from adjacent uplands floods MU2 extensively. These floodwaters are discharged through a one-way tide gate to Hudeman Slough. For several years, MU2 also received a limited amount of tidal flooding through bi-annual opening of another tide gate on Hudeman Creek during extreme high tide events; however, the gate was opened only minimally during the period of this study. Some reclaimed water does enter MU2 borrow ditches during the fall, when reclaimed water from MU3, along with any run-off from several small drainages present, is discharged through the primary borrow ditch along the southern edge of MU2. Once the rains begin, upland run-off and precipitation typically flood not only the primary borrow ditch, but the secondary borrow ditch that parallels Hudeman Creek and the marsh plain itself. It is possible that there may be some overlap between the reclaimed water discharge period and winter rains such that reclaimed water may back-flood into the secondary borrow ditch and onto the marsh plain, but the potential appears minimal, and, in general, any reclaimed water that did back-flood would be diluted substantially by the significant amount of flooding that can occur from upland run-off and precipitation.

While the proximity of MU2 to Management Units 1 and 3 (it falls in between the two reclaimed water units) would suggest that all three should be fairly similar in terms of historical land use, the U.S. Geological Survey (USGS) topographic survey map indicates that MU2 was not fully leveed at the time the map was produced in 1951 (Sears Point quadrangle; Figure 4).

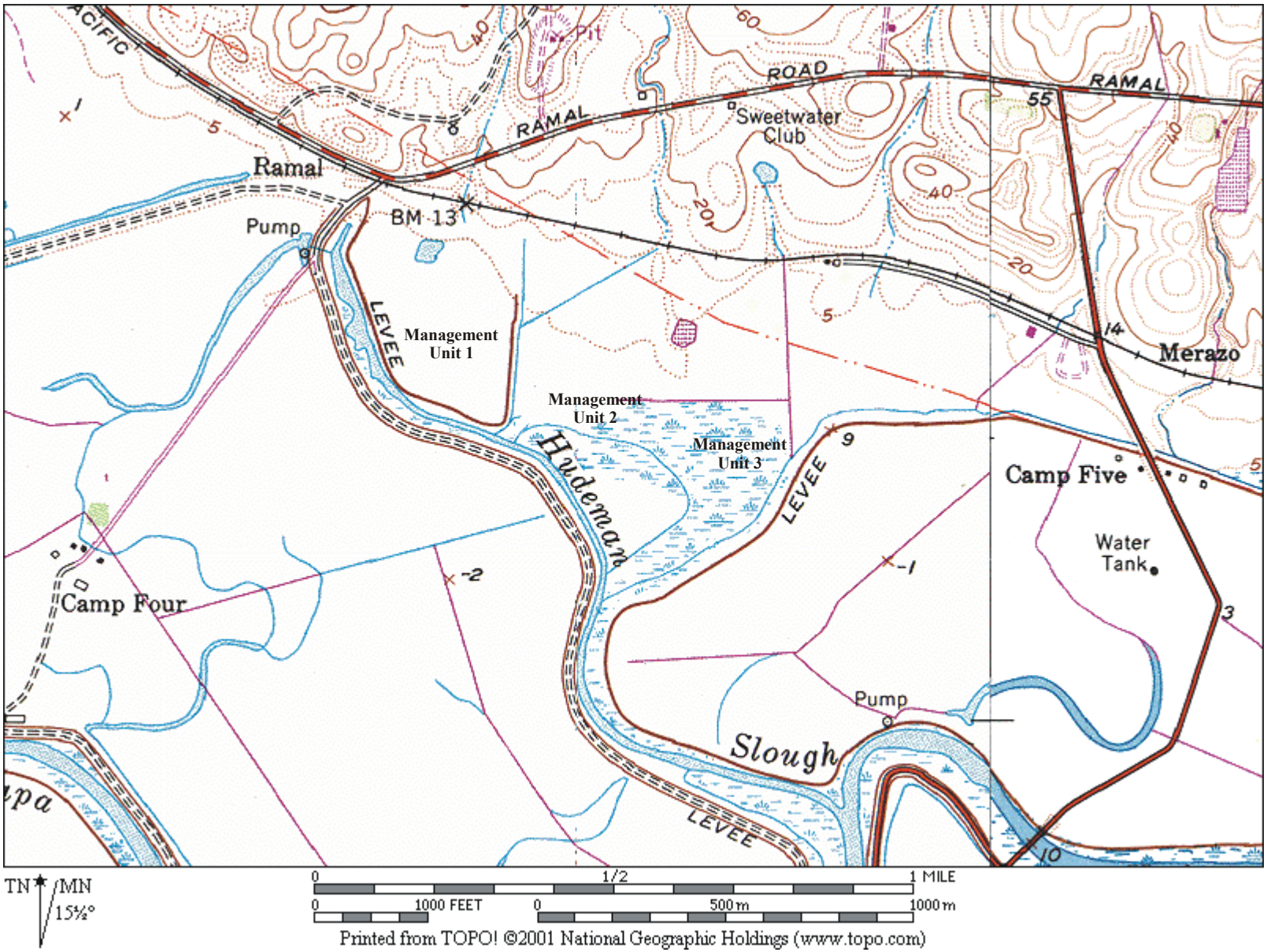

Figure 4. Status of levees at Hudeman Slough Enhancement Wetlands in 1951 (U.S. Geological Survey, Sears Point 7.5 minute quadrangle).

The exact date the levee was constructed is not known, but it may have been as late as the 1970s or early 1980s. The USGS map depicts most of MU2 and a portion of MU3 as marsh, with the upland portions of these units and MU1, which was fully leveed, shown as non-marsh. The upland portions of the Management Units were reputedly farmed until the property's purchase by SVCSD. By the time SVCSD purchased the property, MU2 was leveed adjacent to Hudeman Slough. However, the levee separating Management Units 2 and 3 was built as part of the enhancement project.

Groundwater Pond. The Groundwater Pond is located in CDFG's Huichica Creek Unit (Figure 2). The pond was built for wildlife habitat enhancement in the upland areas bordering the managed diked units. The pond, which is dominated by cattails (*Typha* sp.) and rushes (*Scirpus* sp.), is flooded with pumped groundwater. The pond is re-filled with pumped groundwater over one- to two-week periods each summer (T. Huffman, *pers comm*.).

Hydrologically Unmanaged Monitoring Units

Diked Marsh. The unmanaged, brackish Diked Marsh is located in CDFG's Huichica Creek Unit and is separated from undiked tidal marsh by a railroad berm. The berm restricts tidal influence to high tide events in the creek that bisects the marsh (Figure 2).

Seasonal Ponds. Seasonal Ponds consist of three unmanaged ponds or depressional areas that are inundated seasonally. One of these ponds occurs in the Huichica Creek Unit and is flooded principally with precipitation, some upland run-off, and tidally influenced overflow from a nearby creek (Figure 2). The pond contains a mixture of non-tidal diked subsaline seasonal wetland and seasonal marsh vegetation communities. Another pond is located in the upland portion of Enhancement Wetlands MU2 (Figure 2). The seasonal marsh derives its hydrology exclusively from precipitation and upland run-off. The third pond is located in the upland edge of the Enhancement Wetlands MU3. It is a constructed pond with primarily non-tidal diked subsaline seasonal wetland habitat and also derives its hydrology exclusively from precipitation and upland run-off.

Undiked Marsh. This monitoring unit includes undiked areas adjacent to the Enhancement Wetlands and within CDFG's Huichica Creek Unit (Figure 2). Adjacent to the Enhancement Wetlands are brackish marshes located on the outboard of the levees along Hudeman Slough or at the confluence of Hudeman Slough and Hudeman Creek. The Huichica Creek monitoring sub-unit is a tidal brackish marsh at the uppermost extent of Hudeman Slough near the upland edge, where Huichica Creek flows into San Pablo Baylands. Although the Huichica Creek Unit is hydrologically linked to Schell Slough (point of discharge during winter months), a recent hydrodynamic study conducted for the Napa-Sonoma Marsh Wildlife Area showed that the Enhancement Wetlands and CDFG's Ringstrom Bay Unit principally receive tidal inflow from San Pablo Bay through Sonoma Creek, while CDFG's Buchli Station and Huichica Creek units receive tidal inflow principally from San Pablo Bay through Napa River/Dutchman's Slough (University of California, Davis/U.S. Geological Survey 1999). At least one convergence point of tidal inflow sources occurs in Hudeman Slough between the Enhancement Wetlands and the Huichica Creek Unit (University of California Davis/U.S. Geological Survey 1999).

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